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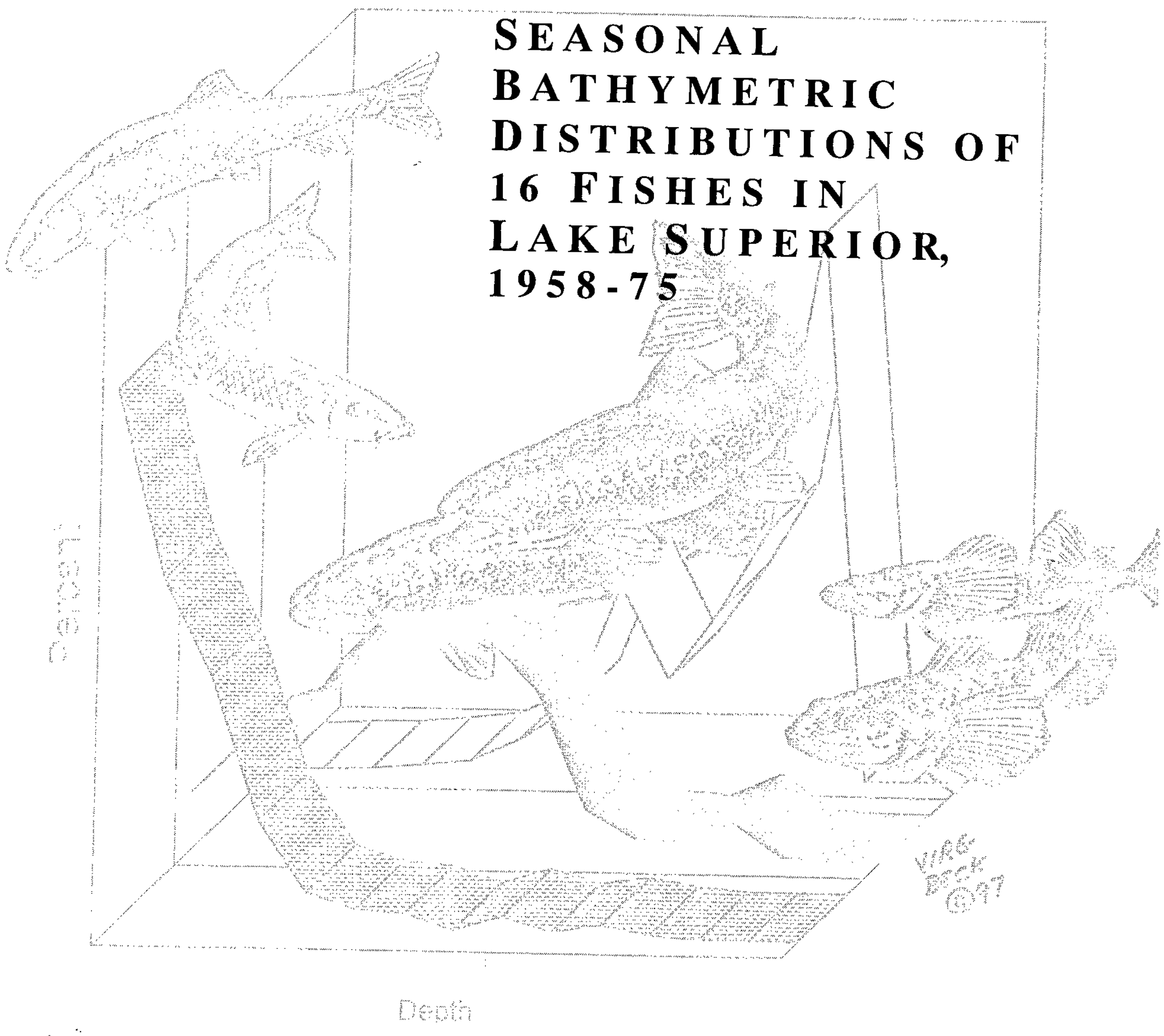
BIOLOGICAL SCIENCE REPORT 7

SEASONAL BATHYMETRIC DISTRIBUTIONS OF 16 FISHES IN LAKE SUPERIOR, 1958-75



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J. H. Selegby and M. H. Hoff

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U.S. Department of the Interior
National Biological Service
Great Lakes Science Center-Lake Superior Biological Station
2800 Lake Shore Drive
Ashland, Wisconsin 54806 U.S.A.

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The bathymetric distributions of fishes in Lake Superior has not been studied on a lakewide scale. Knowledge about the bathymetric distributions will aid in designing fish sampling programs, estimating absolute abundances, and modeling energy flow in the lake. Seasonal bathymetric distributions were determined, by 10-m depth intervals, for 16 fishes collected with bottom trawls and bottom-set gill nets within the upper 150 m of Lake Superior during 1958-75. Bathymetric distributions in spring gill nets were similar to those in trawls, with some exceptions. Lake herring and kiyi were rarely caught in trawls. In summer, pygmy whitefish, shortjaw cisco, lake herring, kiyi, longnose sucker, burbot, ninespine stickleback, trout-perch, slimy sculpin, and spoonhead sculpin were at shallower depths than in spring, whereas rainbow smelt were found in deeper water; there was no change for the other species. In fall, shortjaw cisco was at shallower depths than in summer, whereas the remaining species were found deeper, except for lake whitefish and lake trout whose modal depths did not change. Distributions of lake trout and lake whitefish were also analyzed by age group. The shallow-water species exhibited little seasonal changes in bathymetric distributions, whereas the species that inhabited the middepths and deeper water generally moved shallower as the seasons progressed. Most of the more pronounced seasonal changes in bathymetric distribution were associated with spawning movements.

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SEASONAL BATHYMETRIC DISTRIBUTIONS OF 16 FISHES IN LAKE SUPERIOR, 1958-75

By

James H. Selgeby (Retired)

and

Michael H. Hoff

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Contents

Table

Figures

Seasonal Bathymetric Distributions of 16 Fishes in Lake Superior, 1958-75[1]

by

James H. Selgeby
(Retired)

and

Michael H. Hoff

National Biological Service
Great Lakes Science Center
Lake Superior Biological Station
2800 Lake Shore Drive
Ashland, Wisconsin 54806 U.S.A.

Abstract. The bathymetric distributions of fishes in Lake Superior, which is one of the largest and deepest lakes in the world, has not been studied on a lakewide scale. Knowledge about the bathymetric distributions will aid in designing fish sampling programs, estimating absolute abundances, and modeling energy flow in the lake. Seasonal bathymetric distributions were determined, by 10-m depth intervals, for 16 fishes collected with bottom trawls and bottom-set gill nets within the upper 150 m of Lake Superior during 1958-75. In spring trawl catches, maximum abundance occurred at these depths: 15 m for round whitefish (*Prosopium cylindraceum*); 25 m for longnose sucker (*Catostomus catostomus*); 35 m for lake whitefish (*Coregonus clupeaformis*) and rainbow smelt (*Osmerus mordax*); 45 m for lake trout (*Salvelinus namaycush*); 65 m for pygmy whitefish (*Prosopium coulteri*) and bloater (*Coregonus hoyi*); 75 m for trout-perch (*Percopsis omiscomaycus*); 105 m for shortjaw cisco (*Coregonus zenithicus*); and 115 m for ninespine stickleback (*Pungitius pungitius*), burbot (*Lota lota*), slimy sculpin (*Cottus cognatus*), spoonhead sculpin (*Cottus ricei*), and deepwater sculpin (*Myoxcephalus thompsoni*). Bathymetric distributions in spring gill nets were similar to those in trawls, except that depths of maximum abundances in gill nets were shallower than those in trawls for lake trout, rainbow smelt, longnose sucker, and burbot. Lake herring (*Coregonus artedi*) and kiyi (*Coregonus kiyi*) were rarely caught in trawls, and their maximum abundances in spring gill net collections were at depths of 25 and 145 m, respectively. In summer, pygmy whitefish, shortjaw cisco, lake herring, kiyi, longnose sucker, burbot, ninespine stickleback, trout-perch, slimy sculpin, and spoonhead sculpin were at shallower depths than in spring, whereas rainbow smelt were found in deeper water; there was no change for the other species. In fall, shortjaw cisco was at shallower depths than in summer, whereas the remaining species were found deeper, except for lake whitefish and lake trout whose modal depths did not change. Distributions of lake trout and lake whitefish were analyzed by age group, and the young (ages 1-3) of both species were often found in shallower water than were older fish. The shallow-water species exhibited little seasonal changes in bathymetric distributions, whereas the species that inhabited the middepths and deeper water generally moved shallower as the seasons progressed. Most of the more pronounced seasonal changes in bathymetric distribution were associated with spawning movements.

Key words: Bathymetric distribution, Lake Superior, fishes

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[1]Contribution 962 of the Great Lakes Science Center.

Knowledge of the bathymetric distributions of fishes is needed to design sampling programs that yield data representative of the species, estimate absolute abundances of each species, model the bioenergetics of each species, and model energy flow through the aquatic ecosystem. Such information is essential in understanding and managing large, deep lakes like Lake Superior where fish population densities may vary as widely among depth strata as among geographical areas within the same depth stratum. Information is available on the depth distributions of certain species in the Apostle Islands region of Lake Superior (Dryer 1966), but no such studies have been conducted on a lakewide scale.

We describe the bathymetric distributions for 16 fishes from collections made around Lake Superior during 1958-75. Other indigenous and nonindigenous species are found in Lake Superior, but they were collected too infrequently for us to be able to characterize their seasonal bathymetric distributions. The data that we used in our study were from 6 years of sampling by Dryer (1966) in Lake Superior's Apostle Islands region and from 11 additional years of our own sampling at more than 100 locations in Lake Superior. We used Dryer's (1966) data in conjunction with the more recent data to develop the best available bathymetric distributions for the entire lake.

Materials and Methods

We sampled fishes with bottom trawls and gill nets, with the same methods used by Dryer (1966), at 176 locations in Lake Superior during 1958-75 (Fig. 1). Fishing depths, originally recorded in feet or fathoms, were converted to meters and rounded to the nearest whole meter. Trawl and gill net efforts were summarized by 10-m depth strata, but to simplify data presentation in the text, figures, and tables, only the midpoint of each stratum (e.g., 5 m for the 0-9 m stratum) was used to represent each stratum. Separate bathymetric distributions were calculated for spring (1 April-15 June), summer (16 June-15 September), and fall (16 September-31 December).

Trawls of similar design and size (9.5-m headrope, 13-mm stretched mesh) were used throughout the study for the 3,041 tows taken (Table), but trawl effort was not equal across depth strata or seasons. We fished 15-60-min tows during daylight hours (usually between 0900 and 1600 hours) on

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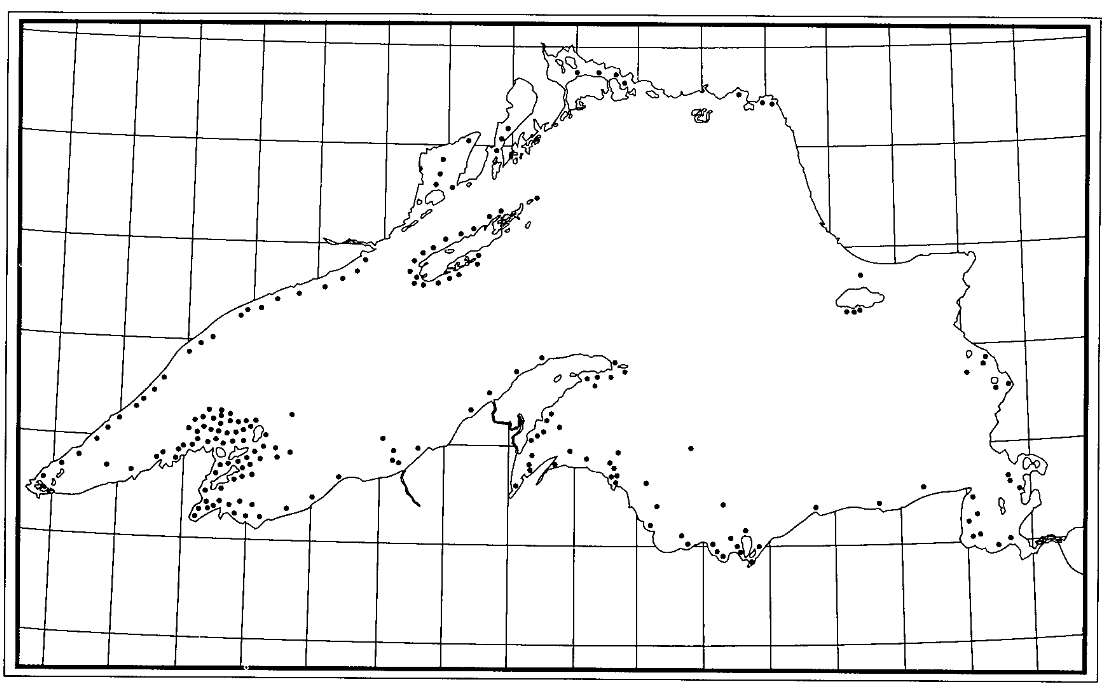

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Fig. 1. Lake Superior showing the locations sampled with trawls and gill nets during 1958-75.

Table. Number of trawl tows and amount of gill-net effort (thousands of meter-nights) in Lake Superior in 1958-74.

	Season					
	Spring 1 April-15 June		Summer 16 June-15 September		Fall 16 September-31 December	
Depth stratum (m)	Trawl (no.)	Gill net meter-nights (x 1,000)	Trawl (no.)	Gill net meter-nights (x 1,000)	Trawl (no.)	Gill net meter-nights (x 1,000)
0-9	9	2.0	36	3.7	2	116.2
10-19	29	0.9	222	8.1	67	74.6
20-29	79	10.1	261	86.8	122	8.8
30-39	145	77.1	264	117.3	110	11.7
40-49	397	181.1	542	165.9	127	14.8
50-59	111	54.0	163	83.8	40	0.5
60-69	29	46.6	121	27.8	18	1.3
70-79	8	2.6	38	9.0	12	0.2
80-89	9	1.0	24	9.5	9	1.1
90-99	7	4.0	21	5.5	7	1.4
100-109	7	0.8	3	3.3	0	0.7
110-119	1	1.7	1	1.9	0	1.1
120-129	0	0.3	0	2.0	0	0.9
130-139	0	0.3	0	7.9	0	0.8
140-149	0	0.7	0	1.1	0	0.7

smooth bottom. Nylon gill nets were uniform in multifilament twine size and hanging characteristics. Nineteen mesh sizes, from 25 mm through 165 mm stretched measure, were fished in 1,378 gill-net sets. A total of 1,151,600 meter-nights (1.0 linear m of net for 1.0 night = 1.0 meter-night) of gill-net effort was used in our analysis (Table). Gill-net effort was not equal across depth strata or seasons. Bathymetric distributions were developed for each species by dividing the mean relative abundance in each stratum, measured as catch-per-unit-effort (CPE), into the mean total CPE for all strata. Catch-per-unit-effort in trawls was the number caught per minute, and in gill nets CPE was the number caught per 1.0 meter-night.

Average water temperatures on the bottom at various depths and seasons were calculated from several thousand bathythermograph casts made during trawling and gill-netting operations.

Seasonal bathymetric distributions of various age groups of lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*) were calculated from sampling conducted in the Apostle Islands region in 1973-75. Gill netting and on-contour trawl sampling were conducted in the Apostle Islands using the same gear and methods as in the other areas of the lake. For lake trout, a series of sets of experimental gill nets (38-, 51-, 64-, 76-, 89-, and 102-mm stretched measure) was made in early October 1975 to determine bathymetric distribution of older native lake trout. Those data were not used in calculating the lakewide average distributions because that sampling effort was small compared with the effort in other areas and years.

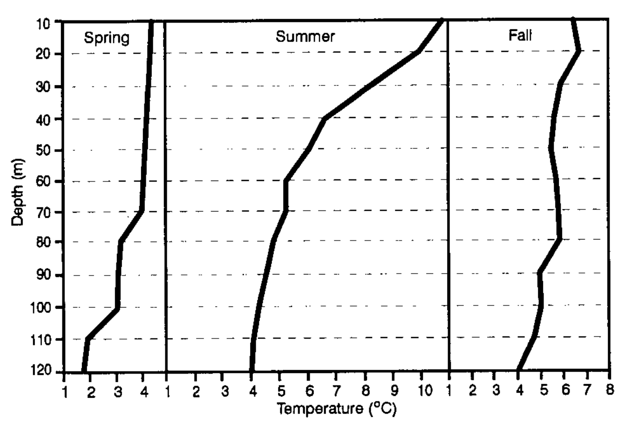


Fig. 2. Average water temperature on the bottom of Lake Superior during spring, summer, and fall.

Results and Discussion

Seasonal Temperatures

Seasonal mean temperature profiles are shown in Fig. 2. Temperatures varied in the water column by less than 3.0 °C in spring and fall, and by more than 6.0 °C in summer, when temperature selection by fishes should be most apparent. We could not examine temperature preferences because temperature data were not available for each trawl tow and gill-net set. However, the seasonal mean temperature data, coupled with seasonal bathymetric distributions for each species, will be useful in modeling species bioenergetics.

Fishing Gear Comparisons

The trawls we used did not commonly capture large individuals or pelagic species such as large lake trout, large lake whitefish, and lake herring (*Coregonus artedi*), so trawls were most efficient for small demersal fishes. Gill nets were frequently fished on rocky bottoms where trawls could not be used. These differences in gear and fishing characteristics, along with differences that presumably occurred among age groups and species in reactions to the sampling gear, resulted in bathymetric distributions that differed between the gear types for some species. In spring, the bathymetric distributions from trawl and gill-net catches differed most for burbot (*Lota lota*) (Fig. 3a), in summer the distributions for the two sampling gears differed most for lake trout (Fig. 3b), and in fall the distributions differed most for longnose sucker (*Catostomus catostomus*) (Fig. 3c).

Lake Trout

In lakewide trawl surveys, lean lake trout were mostly stocked fish ages 1-3. Bathymetric distributions of trawl-caught fish were consistent among seasons (Fig. 4a). Data for all seasons showed that most fish were caught at 35-55 m and that maximum catches were at 45 m. Reigle (1969) found a similar bathymetric distribution for lake trout caught by trawling in Lake Superior during 1963-65.

In lakewide gill-net surveys, lake trout were mostly 4- and 5-year-old stocked fish. Fish were caught at from 5 m to at least 105 m in all seasons, but distributions varied among seasons (Fig. 4b). In spring, most of the fish were at 35-65 m, and maximum abundance was at 35 m. In summer, most fish were distributed over a broader and deeper range, and maximum abundance was at 75 m. In fall, maximum abundance was 15 m, and fish in the 5-25 m strata were mostly spawning adults that were caught on spawning shoals. The all-season abundance mode of gill-netted fish was at 65 m.

In the Apostle Islands, bathymetric distributions for trawl-caught native lake trout ages 1-3 were similar among ages, so catches for these age groups were combined. Maximum abundance for those fish was found at 45 m in spring, at 55 m in summer, and at 45 m in fall (Fig. 5). In fall, almost all 1-3-year-old lake trout were found in water shallower than 45 m.

Bathymetric distributions for Apostle Islands native lake trout, caught in experimental gill nets during early October 1975, were analyzed by age group. That analysis revealed three dissimilar distributions: age 1-3 fish were most abundant at 45 m; age 4-5 fish were evenly distributed among the 25-85 m strata; and age 6-11 fish were most abundant at 75 m (Fig. 6).

Our bathymetric distribution data from the Apostle Islands region agreed well with our data from the remainder of the lake. In spring and summer, the distributions of trawl-caught age-1-3 lake trout that we found were similar to those described by Eschmeyer (1956) for age-1 and age-2 Lake Superior lake trout. However, he did not document the shallow-water distribution that we found in fall. In Lake Ontario, stocked age-2 lake trout were most abundant at 35-55 m in spring, at 25-35 m in summer, and at 35-45 m in fall (Elrod and Schneider 1987). Thus, fish in Lake Ontario occupied shallower water in all seasons than they did in Lake Superior. In Great Bear Lake, as in our study, lake trout were most abundant in water less than 80 m deep, although some fish were collected as deep as 400 m (Johnson 1975).

Lake Whitefish

Lake whitefish caught in lakewide trawl surveys were mostly ages 1-3, and age-0 fish were only caught in trawls. Most fish caught in gill nets were ages 4 and older.

Trawl-caught lake whitefish were found at 15-85 m. Most of those fish were caught at 25-45 m in each season, and the all-season modal depth was at 35 m (Fig. 7a). Thus, the bathymetric distribution of those fish varied little among seasons.

Gill-netted lake whitefish were found in the 5-145 m strata, but few were caught at depths greater than

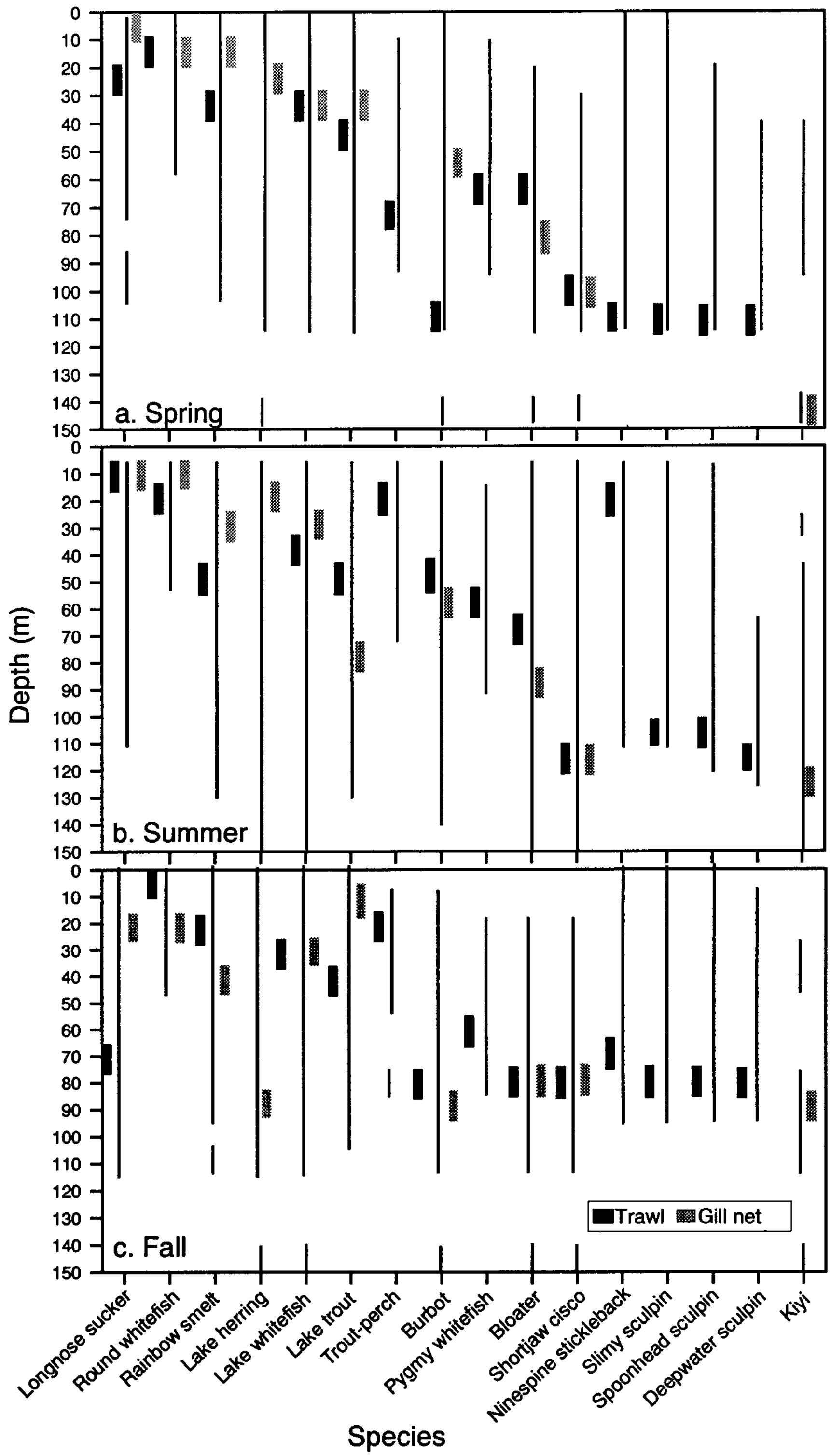


Fig. 3. Bathymetric distributions of 16 Lake Superior fishes in spring, summer, and fall.

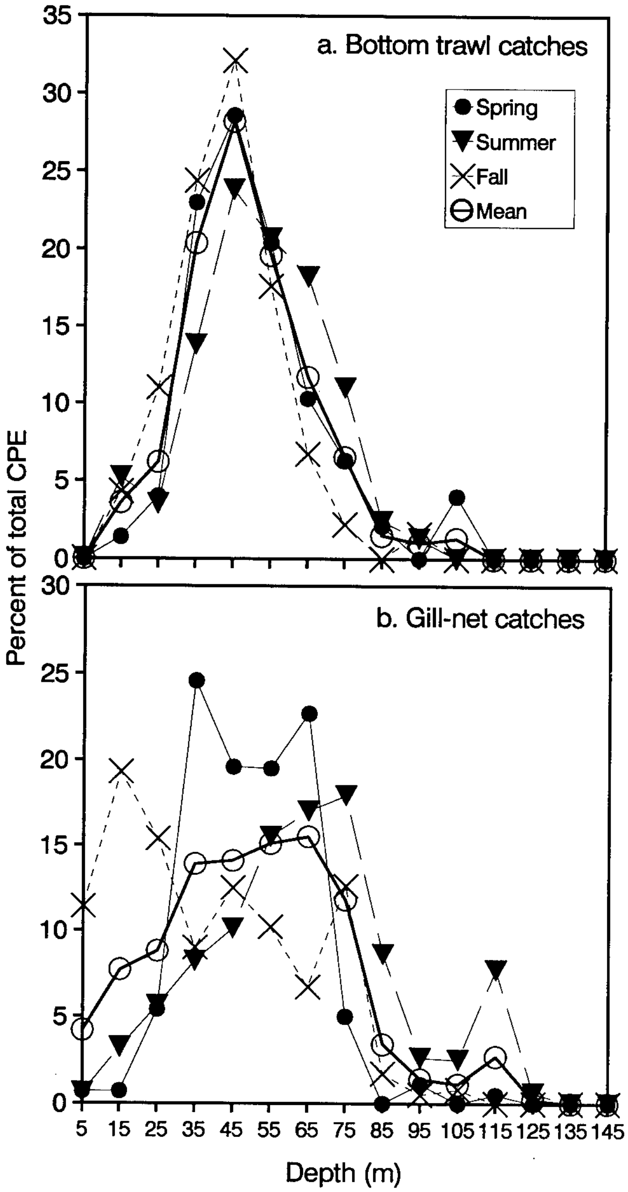


Fig. 4. Seasonal bathymetric distributions of lake trout, based on catch-per-effort (CPE) in bottom trawl and gill-net catches in Lake Superior during 1958-74.

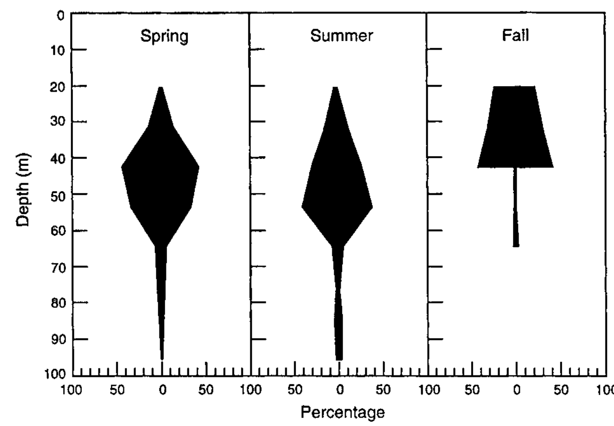


Fig. 5. Seasonal bathymetric distributions of age 1-3 lake trout, based on percentage of catch-per-effort (CPE) in bottom trawl catches, in the Apostle Islands region of Lake Superior during 1973-74.

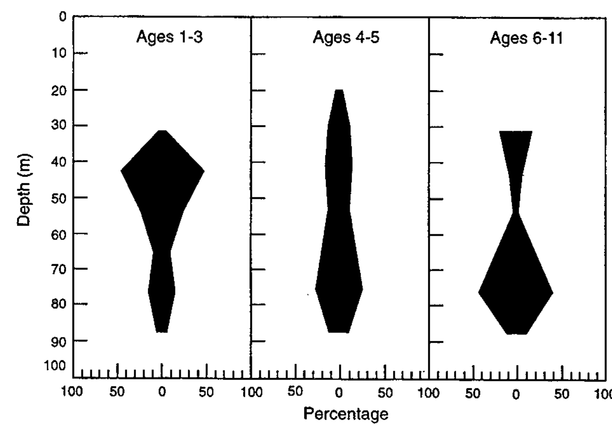


Fig. 6. Bathymetric distributions for three age groups of native lake trout, based on percentage of catch-per-effort (CPE) in gill-net catches, in the Apostle Islands region of Lake Superior during 6-8 October 1975.

65 m. The abundance mode for those fish was either at 25 or 35 m in each season, and most of the fish were collected at 25-55 m in all seasons (Fig. 7b).

The greatest disparity in findings between trawl and gill-net sampling occurred during fall, when gill-net sampling showed a bimodal frequency distribution by depth. At that time, many large fish were at 5 m, and many smaller fish were at 25-45 m. We believe that the large fish at 5 m were spawning adults.

In the Apostle Islands region during 1973-75, age-0 lake whitefish were most abundant in trawls at 20 m in mid to late September, but by early November the fish had moved about 9 m deeper (Fig. 8). Age-1 fish were mostly at 29-48 m in May-August, but by September they had moved up to the shallower depths occupied by age-0 fish. Age-2 fish were at 38-66 m in May-August (Fig. 8), but they were at nearly the same shallow depths in September-November as the age-0 and age-1 fish. Age-3 and older fish were evenly distributed between 28 and 72 m in May, and between 46 and 82 m in June. In August there were two distinct distributions, at 27-38 m and at 65-75 m.

In September, the fish were concentrated at 28-37 m, but by November the fish were distributed evenly over the broad range from 18 to 84 m.

The bathymetric distributions for small and large lake whitefish that we documented were similar to the distributions described by Koelz (1929) in Lake Superior. In Great Bear Lake, most fish were found in shallow bays at depths less than 30 m (Johnson 1975), which was similar to the average distribution in Lake Superior. In Great Bear Lake, juvenile fish were rarely found, and most of those were collected along the deepest habitat occupied by adults (Johnson 1975). That pattern was dissimilar to the one we documented during fall for fish in the Apostle Islands, where age-0 fish were also found in the shallowest habitat occupied by adults.

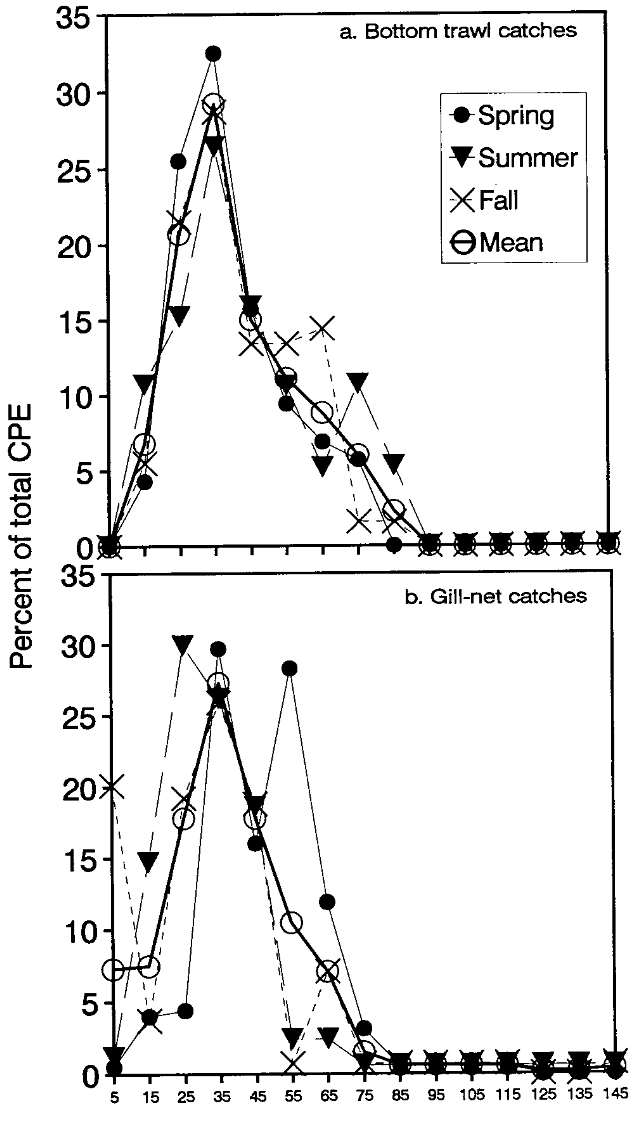


Fig. 7. Seasonal bathymetric distributions of lake whitefish, based on catch-per-effort (CPE) in bottom trawl and gill-net catches, in Lake Superior during 1958-74.

Lake Herring

The lake herring is a pelagic species that was rarely caught in our trawls, so we did not analyze the seasonal bathymetric distributions of this species from trawl sampling. We caught lake herring in lakewide gill-net surveys at all depths, where most were probably caught when schooled fish encountered sloping banks. In spring and summer, most fish were caught at 15-65 m and 5-25 m, respectively, when abundance modes were at 25 m in spring and 15 m in summer (Fig. 9a). Catches were much

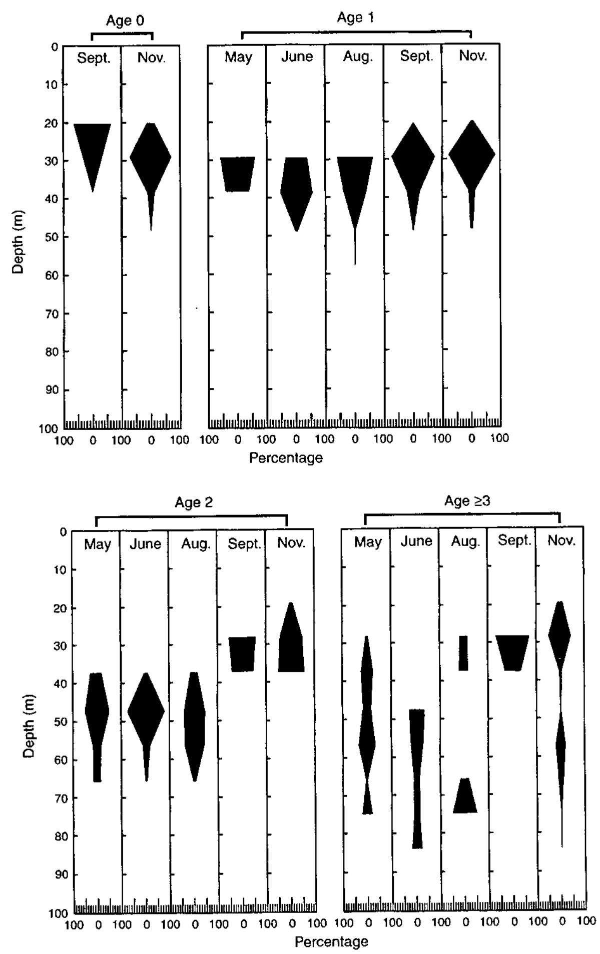


Fig 8. Bathymetric distributions of age-0, age-1, age-2 and age $\geq$ 3 lake whitefish, based on catch-per-effort (CPE) in bottom trawl catches, in the Apostle Islands region of Lake Superior, 1973-75.

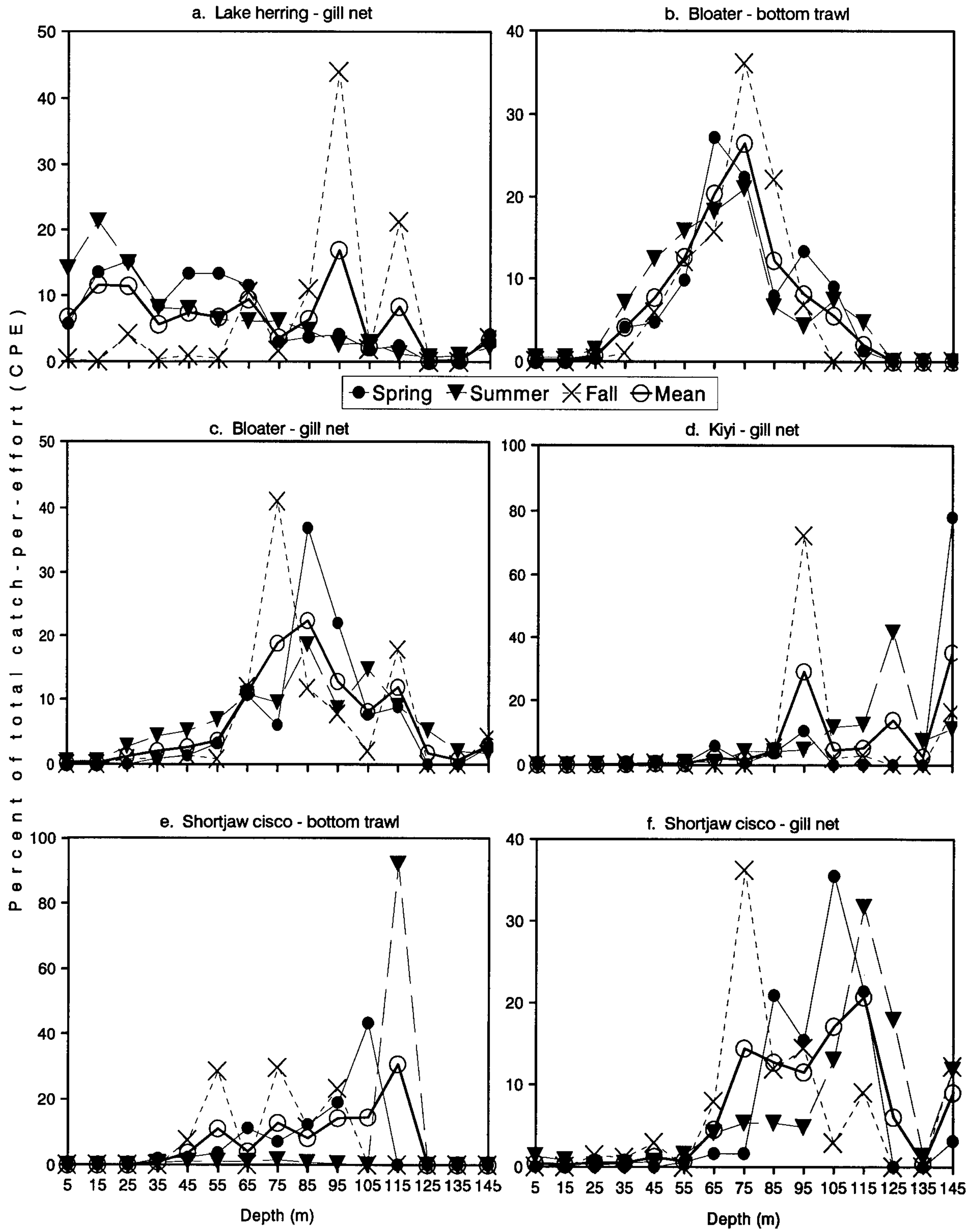
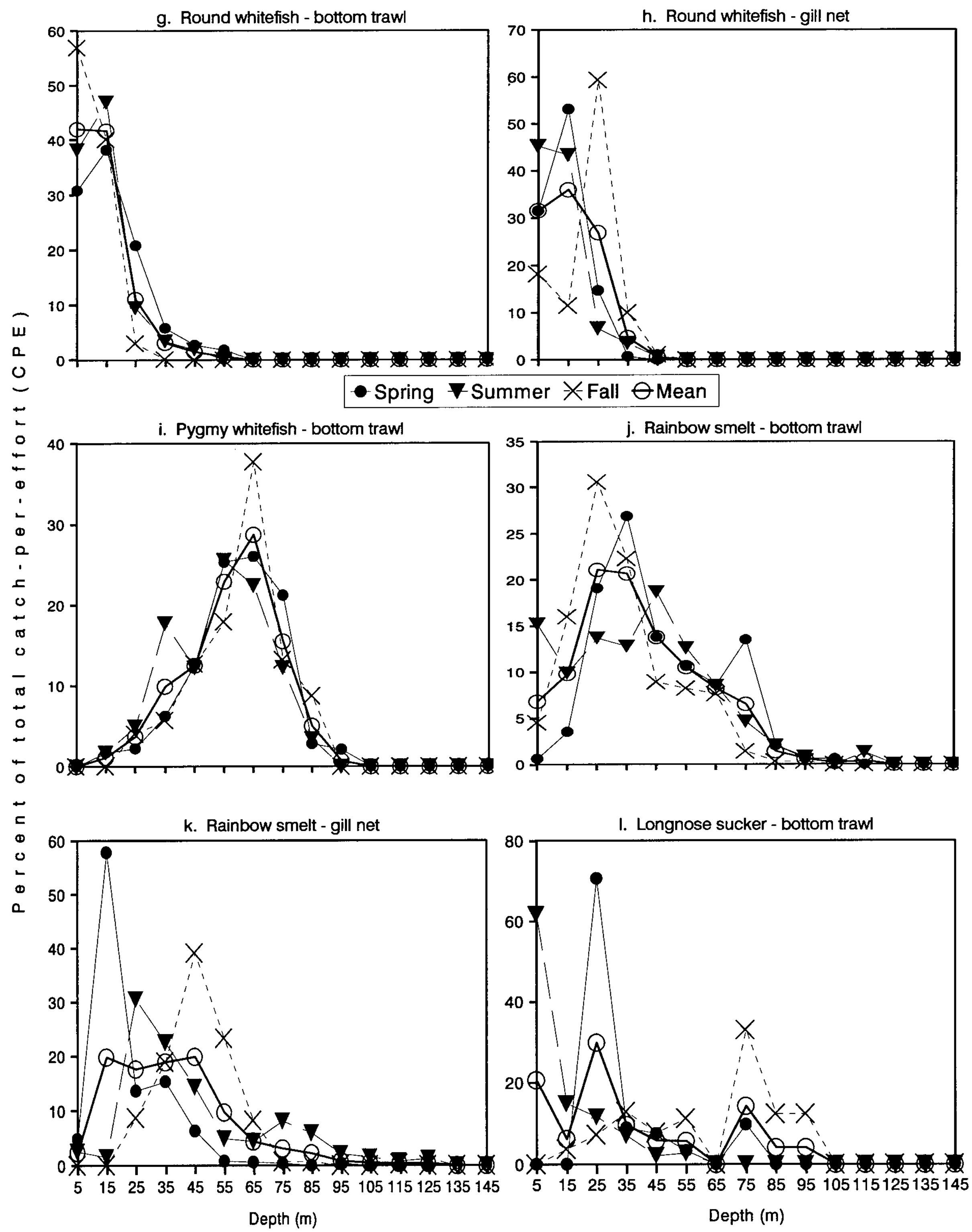


Fig. 9. Seasonal bathymetric distributions of 14 fishes, based on catch-per-effort (CPE) in bottom trawl and gill-net catches, in Lake Superior during 1958-74.



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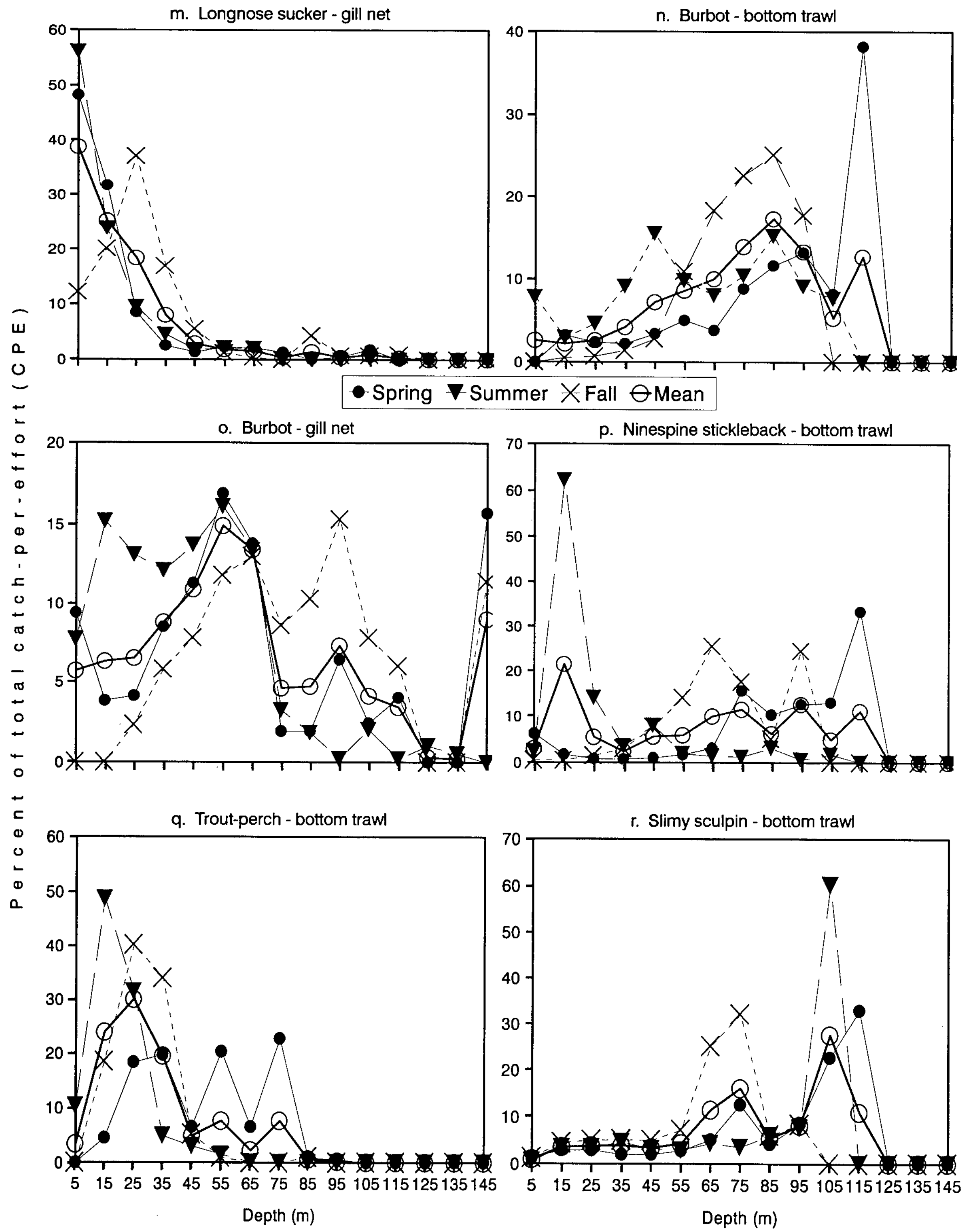

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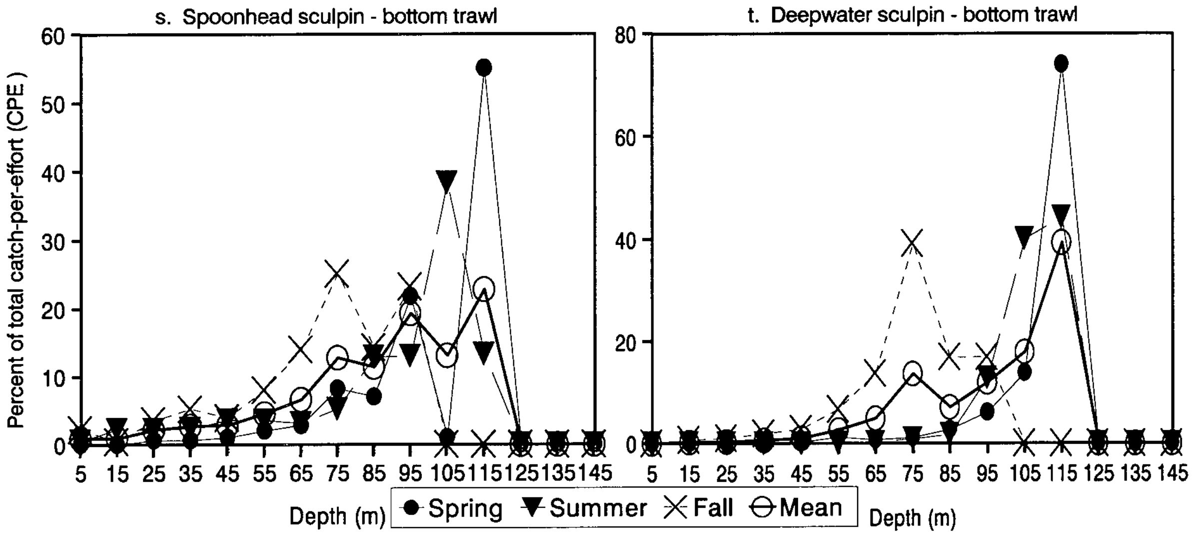

Fig. 9. Continued.

smaller in spring and summer than in fall, when most fish caught were spawning adults that had congregated near the lake bottom before spawning. In fall, abundance was trimodal, although maximum abundance was at 95 m. The three modes were presumably the depths of different spawning grounds that were sampled.

Bloater

Bloaters (*Coregonus hoyi*) were caught in surveys at all depths sampled. Fish caught in trawls tended to be smaller and younger than those caught in gill nets. The abundance mode for trawl-caught fish was at 65 m in spring and at 75 m in summer and fall (Fig. 9b). The abundance modes for fish gill-netted in spring and summer were at 85 m, but the mode was 75 m in fall (Fig. 9c). Thus, small fish moved deeper after spring, whereas larger fish moved shallower after summer. In all seasons, most of the trawl-caught fish were at 55-85 m, whereas most of the gill-netted fish were at 75-95 m. The all-season abundance mode was 75 m for trawl-caught fish and 85 m for gill-netted fish. In Lake Michigan, Wells (1968) described much greater movement of bloater toward shallow water during summer than we found in Lake Superior. In spring and fall, distributions of trawl-caught Lake Michigan bloaters (Wells 1968) were similar to the distributions that we documented in Lake Superior.

Kiyi

Few kiyis (*Coregonus kiyi*) were caught in trawls, so we did not report seasonal bathymetric distributions from trawl catches. Kiyis were caught with gill nets as shallow as 45 m in spring, 25 m in summer, and 35 m in fall (Fig. 9d). Because fish abundance was greatest at the greatest depth that we sampled in spring (145 m), the depth of maximum relative abundance was presumably deeper than that. As the seasons progressed, the depth of the abundance modes decreased. In fall, fish in the concentration at 95 m were presumably spawners. In all seasons, most fish were collected at 95 m and at 125-145 m, and the all-season abundance mode was at 145 m. Koelz (1929) found that the kiyi was abundant as deep as 180 m in Lake Superior, so we may not have sampled deep enough to find the true depth mode in Lake Superior.

Shortjaw Cisco

Shortjaw ciscoes (*Coregonus zenithicus*) were caught in lakewide trawl and gill-net surveys at 5-145 m (Fig. 9e, f). Maximum abundances in both trawls and gill nets were at 105 m in spring and at 115 m in summer, but they were at 75 m in the fall. The shallower distributions in fall were probably associated with spawning concentrations. In all seasons, most trawl-caught fish were at 95-115 m, whereas most gill-netted fish were at 85-115 m. The all-season abundance modes of fish in both trawls and gill nets were at 115 m.

Round Whitefish

Round whitefish (*Prosopium cylindraceum*) were caught in lakewide trawl and gill-net surveys at 5-55 m, although few were caught deeper than 25 m (Fig. 9g and 9h). In spring and summer, abundance modes for fish caught in trawls and gill nets were either at 5 or 15 m. In fall, the abundance mode of trawl-caught fish was at 5 m, while that for gill-netted fish was at 25 m. Those differences were due to the large numbers of age-0 fish caught in trawls at 5 m, and to the large numbers of adults caught in gill nets at 25 m. In all seasons, most of the fish were at 5-25 m, when the abundance mode for trawl-caught fish was at 5 m, and the mode for gill-netted fish was at 15 m.

Pygmy Whitefish

Pygmy whitefish (*Prosopium coulteri*) were not caught in gill nets but were caught in lakewide trawl surveys at 15-95 m (Fig. 9i). Most fish were either at 55-65 or 45-65 m in each season, and the all-season abundance mode was at 65 m.

The all-season depth of maximum abundance that we documented around Lake Superior for pygmy whitefish agreed well with the distribution described by Eschmeyer and Bailey (1955) for fish in Keweenaw Bay of Lake Superior.

Rainbow Smelt

Rainbow smelt (*Osmerus mordax*) were caught in lakewide trawl and gill-net surveys at 5-125 m (Fig. 9j and k). Trawls caught fish of all ages, whereas gill nets caught mainly adults. In spring, the abundance mode for trawl-caught fish was at 35 m (Fig. 9j), while that for gill-netted fish was at 15 m (Fig. 9k). In spring, adult fish were concentrated in the shallows before and after spawning on beaches and in rivers. In summer, trawl-caught fish were mostly juveniles and were most abundant at 25-55 m, while gill-netted fish were most abundant at 25-35 m. In fall, trawl-caught fish were most abundant at 25-35 m, while gill-netted fish were most abundant at 45-55 m. In all seasons, the abundance mode for trawl-caught fish was at 25 m, whereas the mode for gill-netted fish was at 45 m.

The distributions we documented showed that adult rainbow smelt were found at shallower depths in the spring, and at deeper ones in summer and fall, whereas juvenile fish were found deep in the spring, and at shallower depths in summer and fall. The distributions that we found were similar to those seen by Wells (1968) in Lake Michigan; however, fish there were found only as deep as 70 m, whereas we found them as deep as 125 m.

Longnose Sucker

Most longnose suckers caught in lakewide trawl and gill-net surveys were large juveniles (200 mm long) and adults found at 5-95 m (Fig. 9l and 9m). In spring, the abundance mode for trawl-caught fish was at 25 m, while that for gill-netted fish was at 5 m. In summer, the abundance mode from sampling with both gears was at 5 m, whereas in fall the mode for trawl-caught fish was at 75 m and that for gill-netted fish was at 25 m. In all seasons, most of the fish caught in both sampling gears were at 5-25 m. The all-season abundance mode of trawl-caught fish was at 25 m, and that of gill-netted fish was at 5 m.

Burbot

Burbots were caught in lakewide trawl and gill-net surveys at 5-145 m (Fig. 9n and 9o). There was little similarity in the bathymetric distributions from trawl and gill-net catches in spring. In spring trawl catches, burbots were caught in the 15-115 m strata, and abundance increased with depth. In spring gill-net catches, abundance was not related to depth, but abundance was highest at 55 m. In summer, burbot were found shallower than in spring, but trends in depth distributions between the sampling gears again differed. In fall, distributions from trawl and gill-net catches were more similar than they were in spring and summer. In all seasons, most of the trawl-caught fish were at 65-115 m, whereas most of the gill-netted fish were at 15-65 m. The all-season abundance mode for trawl-caught fish was at 85 m, whereas that for gill-netted fish was at 55 m. Differences between spring trawl and gill-net collections were presumably due to differential catchability between gear types for various size and age groups. Catches in both gear types suggested that burbot moved into deeper waters from summer to fall.

Ninespine Stickleback

Ninespine sticklebacks (*Pungitius pungitius*) were caught in lakewide surveys only in trawls and were at 5-115 m (Fig. 9p). In spring, the abundance mode was at 115 m, although a secondary abundance mode at 5 m was presumably the result of an in-shore pre-spawning congregation of adults. In summer, the abundance mode was at 15 m, where adults presumably congregated for spawning. In fall, the abundance mode was at 65 m. In all seasons, most of the fish were at 15-65 m, and the all-season abundance mode was at 15 m.

Trout-perch

Trout-perch (*Percopsis omiscomaycus*) were caught during lakewide surveys only in trawls and were at 5-95 m (Fig. 9q). In spring, the abundance mode was at 75 m, although abundance was also high at 25, 35, and 55 m. In summer and fall, the modes were at 15 and 25 m, respectively. In all seasons, most fish were at 15-35 m, and the all-season abundance mode was at 25 m.

In Lake Superior, trout-perch were generally deeper than in Lake Michigan (Wells 1968) in spring and summer. In fall, the bathymetric distributions for trout-perch in the two lakes were similar.

Slimy Sculpin

Slimy sculpins (*Cottus cognatus*) were caught in lakewide trawl surveys at 5-115 m (Fig. 9r). The abundance mode was at 115 m in spring, at 105 m in summer, and at 75 m in fall. Thus, the fish moved shallower as the seasons progressed. In all seasons, most of the fish were at 65-115 m, and the all-season abundance mode was at 105 m.

In Lake Superior, slimy sculpins were generally deeper than in Lake Michigan (Wells 1968), and catches in the two lakes showed different seasonal distributions. In Lake Michigan, catches were most abundant at depths less than 50 m in spring, but thereafter they were found deeper (Wells 1968). In Lake Superior, data from our study and that from Selgeby's (1988) study showed that slimy sculpins apparently moved shallower from spring to fall. In Great Bear Lake, slimy sculpins were largely restricted to the upper 3 m (Johnson 1975), which is a much narrower and shallower distribution than in Lake Superior.

Spoonhead Sculpin

Spoonhead sculpins (*Cottus ricei*) were caught in lakewide trawl surveys at 5-115 m (Fig. 9s). As with slimy sculpins, maximum abundance of spoonhead sculpins was at 115 m in spring, at 105 m in summer, and at 75 m in fall. Thus, spoonhead sculpins, like slimy sculpins, moved shallower as the seasons progressed. In all seasons, most of the fish were found at 95-115 m, and the all-season abundance mode was at 115 m.

Selgeby (1988) studied the bathymetric distributions of spoonhead sculpin in the Apostle Islands in 1972-73 and found that the abundance mode was at 85 m in spring and summer and at 65 m in fall. Thus, the modes in Selgeby's (1988) study were shallower than those found in our lakewide study.

Deepwater Sculpin

Deepwater sculpins (*Myoxcephalus thompsoni*) were caught in lakewide trawl surveys at 15-115 m (Fig. 9t). Bathymetric distributions of deepwater sculpins were similar to those described for slimy and spoonhead sculpins. Maximum abundance of fish was at 115 m in spring and summer and at 75 m in fall. The population sampled in fall was composed mainly of immature and small adult fish. In all seasons, most fish were at 75-115 m, and the all-season abundance mode was at 115 m.

The seasonal distributions that we developed from lake-wide catches were similar to those described by Selgeby (1988) for fish in the Apostle Islands region, but he also collected deepwater sculpins in a gill-net set at 407 m, which is the maximum reported lake depth. Selgeby (1988) concluded that large fish were at depths greater than 90 m in spring and summer, and that they moved deeper by fall, when smaller fish moved shallower.

In Lake Michigan, only one deepwater sculpin was found shallower than 57 m, and maximum abundance was at 82-91 m in all seasons (Wells 1968). In Great Bear Lake, deepwater sculpins were collected at 3-220 m, but specimens were found in stomachs of lake trout caught at 396 m, so this species may occupy the deepest water of the lake (Johnson 1975).

Summary

Bathymetric distributions of the 16 Lake Superior fishes that we studied formed a continuum, from fishes that generally inhabited water shallower than 25 m (longnose sucker and round whitefish) to fishes that generally inhabited water deeper than 75 m (deepwater sculpin and kiyi). Species that mostly inhabited shallow water in spring generally showed little seasonal changes in bathymetric distributions, whereas the species that mostly inhabited the mid-depths and deeper water in spring generally moved shallower as the seasons progressed. Thus, species that inhabited shallow water in spring were generally less dispersed across depths than were fishes that mostly occupied middepths and deep water in spring. Most of the more pronounced seasonal changes in bathymetric distribution were apparently associated with spawning movements.

Research Needs

Several species were not collected in numbers large enough to analyze during this study. Some of those species are important to modeling energy flow in the Lake Superior aquatic ecosystem, so their seasonal bathymetric distributions need to be documented. Those species include siscowet lake trout (*Salvelinus namaycush siscowet*), chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*). Data are also needed on bathymetric distributions by age and size for species other than lake trout and lake whitefish.

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J. H. Selegby and M. H. Hoff

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The bathymetric distributions of fishes in Lake Superior has not been studied on a lakewide scale. Knowledge about the bathymetric distributions will aid in designing fish sampling programs, estimating absolute abundances, and modeling energy flow in the lake. Seasonal bathymetric distributions were determined, by 10-m depth intervals, for 16 fishes collected with bottom trawls and bottom-set gill nets within the upper 150 m of Lake Superior during 1958-75. Bathymetric distributions in spring gill nets were similar to those in trawls, with some exceptions. Lake herring and kiyi were rarely caught in trawls. In summer, pygmy whitefish, shortjaw cisco, lake herring, kiyi, longnose sucker, burbot, ninespine stickleback, trout-perch, slimy sculpin, and spoonhead sculpin were at shallower depths than in spring, whereas rainbow smelt were found in deeper water; there was no change for the other species. In fall, shortjaw cisco was at shallower depths than in summer, whereas the remaining species were found deeper, except for lake whitefish and lake trout whose modal depths did not change. Distributions of lake trout and lake whitefish were also analyzed by age group. The shallow-water species exhibited little seasonal changes in bathymetric distributions, whereas the species that inhabited the middepths and deeper water generally moved shallower as the seasons progressed. Most of the more pronounced seasonal changes in bathymetric distribution were associated with spawning movements.

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